

Jack Bristor (A)

Open Channel Flow

In the winter of 1953 a sudden partial stoppage of flow in the St. Clair and Detroit Rivers which connect Lakes Huron, St. Clair, and Erie threatened to flood several communities along the banks. The Detroit District, Corps of Engineers, U.S. Army, was responsible for constructing and maintaining navigation channels in the two rivers and also for doing all in its power to prevent floods along their banks. In charge of the District Office was Colonel John D. (Jack) Bristor, the District Engineer.

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Prepared by Professor John D. Bristor, University of Florida, during the
Summer Institute for Case Methods supported by the National Science Founda-
tion at the Stanford School of Engineering, 1967. Names disguised.

One morning in the winter of 1953, Jack Bristor was sitting in a commuter train winding its way along the Detroit River into the Brush Street Station. As he looked up from the Detroit Free Press, he noticed that the river appeared to be frozen solid. The ice was not a single sheet, but was composed of large chunks, some as large as 6' x 20' and about 6 to 8 inches thick. These pieces of ice were piled in random fashion 4 or 5 feet high, and were cemented together by a new layer of ice.

"I remember thinking that the rum runners who used the ice to carry their liquor across from Canada during Prohibition would have had a tough time on that surface," he recalled. "I supposed it had been caused by the unusual pattern of winter weather. December, January, and early February were so moderate that Detroiters talked jokingly about being in the 'Banana Belt'. Then in the middle of February, it had turned very cold, with temperatures down to -10°F. There had been a short thaw, followed by another cold wave."

Upon arrival at the District Office, Jack was greeted by Mr. Joe Darcy, Chief of Operations. Joe was a graduate civil engineer, who had worked his way up from a surveyman on the rivers and the Great Lakes, and who had about 22 years with the District. Joe said, "Jack, it looks like something is blocking the flow in both the St. Clair and Detroit Rivers. The Algonac gage (Maps are shown in Exhibit A-1) has been rising since yesterday noon. Gibraltar and Ft. Wayne have been erratic, but the trend seems to be up." Jack asked about Lake St. Clair and was told that the Grosse Point Yacht Club and Windmill Point Gages seemed to be steady, but that some of the readings were missing.

Jack then asked Joe, "What can we do about that?" Joe replied, "Gosh, I don't know. There doesn't seem to be anything we can do." Bristor then asked Darcy to arrange to have hourly gage readings along the two rivers and Lake St. Clair telephoned into the office. Joe said that he had been to four points on the Detroit River the day before and that the river looked just like it did to Bristor from the train.

"It really puzzles me that both rivers are rising," Jack said. "I wonder if aerial reconnaissance would tell us anything." Joe replied: "From what I saw yesterday, I don't think so, but it certainly can't hurt."

Bristor had received a master's degree from Cornell about 15 years before, majoring in hydraulics. However, his thesis related to beach erosion. He recalled having studied open channel flow, but did not specifically remember the effect of ice, as the emphasis had seemed to be on transportation and sedimentation of material (soil) in rivers in alluvial valleys. At Cornell, he had stream-gaged a small river from an aerial tramway, and he had visited a catamaran survey party taking flow measurements in the St. Clair River three years before.

The Army Engineers had two districts in Detroit: the Detroit District, of which Col. Bristor was head, performed construction, operation, and maintenance in the area; the U. S. Lake Survey, which had a different district engineer (but which Bristor had headed in 1949-50) surveyed the Great Lakes and their connecting channels, studied the hydrology of the Great Lakes, and kept records of lake levels and river flows. From his Lake Survey experience, Bristor had obtained the following facts and impressions about the two rivers and Lake St. Clair:

The two rivers varied in width from about 1/2 to 3-1/2 miles; through each was a navigation channel 25' in depth and a minimum width of 600'. Lake St. Clair was about 20 miles in diameter, and generally fairly shallow, with maximum natural depths up to 21'. A navigation channel of the same minimum size as the rivers crossed the lake. Profiles of the rivers at two points are shown in Exhibit A-2.

Flow in the two-river one-lake system depended on the relative heights above sea level of Lake Huron and Lake Erie and was generally an exponential function of the difference in elevation of the two major lakes. The equations for these flows, contained in Exhibit A-3, had been carefully checked by stream-gaging. At the moment, flows in the two rivers were at a record high for February, though they had been higher in other months. Exhibit A-4 shows historical flow rates over a period of years.

There were three gages along each river and one on Lake St. Clair. Maps showing the rivers and gage locations appear in Exhibit A-1. The gages were spring powered and had automatic recording charts which plotted changes in water level throughout the day, but they could also be read manually at any time. A gage reader tended them normally once per day to wind the gages, replace the charts and see that they were operating normally. High precision measurements were made to calibrate the gages, and these had shown the gages to be accurate to within 1/100 foot. Each gage was located in a shelter which protected it from weather and waves. Exhibit A-5 depicts the recording mechanism and Exhibit A-6 shows a typical recording taken from a gage.

Complete records of lake levels had been maintained since 1860. Some fragmentary records dating back to 1836 were also available. Consequently, by examining hydrographs (time versus water level curves), it was possible to determine the levels of all lakes at any time within the past 92 years. By correlating this information, gage heights at any point and flows could be determined for any time during this period.

The St. Clair River-Lake St. Clair-Detroit River system contained no regulating works (gates). There were, however, gates (and power plants) on the St. Mary's River (Exhibit A-1), which connected Lake Superior and Lake Huron. These gates could vary the flow into Lake Michigan-Huron from Lake Superior from 2,000 c.f.s. to 130,000 c.f.s.

At times in the past, strong northerly winds had tended to pile up the water in Lake Huron so as to raise the elevations at the south end. This rise in head produced a flood crest which could be traced as it passed down the St. Clair River. Lake St. Clair damped out the crest, however, and there seemed to be no logical explanation for the rise in the Detroit River.

Along the St. Clair River, on both the Michigan and Ontario sides, were a number of small, rather low-lying towns and cities. There was industrial and residential development on Lake St. Clair, in addition to an

Air Force Base. Both banks of the Detroit River were highly industrialized from Lake St. Clair downstream for a distance of about 30 miles. Beyond that, the land was used for residential and agricultural purposes. Railroad tracks from Toledo to Detroit paralleled the Detroit River, being quite close to the water in some locations. Col. Bristor realized that continued rise of water levels would probably cause severe property damage and possibly even loss of life.

After his conversation with Joe Darcy, Jack Bristor telephoned his friend Bill (Chop) Sticks, who commanded Selfridge Air Force Base, about 30 miles from downtown Detroit. He described what he knew of the situation and asked if Sticks would send a reconnaissance aircraft over the rivers and Lake St. Clair. Sticks, after making it clear that his aircraft were not under the operational control of the Army, readily agreed to have the mission flown. He offered the services of a trained aerial observer, or alternatively, to allow one of Bristor's engineers to come along. Bristor weighed the fact that the mission could be expected to get off the ground two hours sooner with an Air Force observer against his belief that one of his own engineers might know better what to look for. "OK, Chop, send your own man, and ask him to look particularly for any large ice jam. Probably the lower he can fly, the better. If you'd have him phone me as soon as he lands, I'd appreciate it."

At this point, the mayor of Algonac, a small city on the west bank of the St. Clair River, telephoned and said that downtown Algonac was covered with a foot of water, that the Army Engineers were responsible for preventing that sort of thing and that they should do something about it right now. Bristor expressed his regret about the flooding, told the mayor that excessive rainfall over the upper Great Lakes was responsible, and gave his assurance that the matter was being investigated at the moment. Exhibit A-7 gives long-term gage readings at Algonac.

"My usual approach to a difficult problem like this is to mobilize all the resources of the District, especially its best brainpower, to tackle the job," Jack commented. "I happen to believe that an engineering manager

should make decisions on the basis of the fullest information and the best technical knowledge he can get. I use personal observation, study, and 'picking the brains' of my staff until I figure out what to do. Sometimes this makes me a little unpopular with some of the experts who think their word should be accepted as Gospel, but I think it works."

For this reason, Jack decided to call a conference of the people whom he felt knew most about lake levels and flow in the system. He telephoned each of the following, briefly describing the situation, asking him to meet in about an hour, and requesting that each bring along any useful data he could assemble in that period:

Joe Darcy, Chief of Operations, Detroit District, previously mentioned.

Mel Jones, Chief of Engineering of the Detroit District. Mr. Jones, a graduate electrical engineer, had been with the District since the early 1920's.

Phil Ash, Chief of Design of the Detroit District, a graduate engineer with about 15 years experience, including a great deal of field work on the rivers.

Frank Brown, Chief Hydrologist of the U.S. Lake Survey, a graduate engineer who had devoted over 25 years to the study of lake levels and flow in the connecting channels. Jack Bristor admired Mr. Brown's technical competence and his ability to back up any statement he made with records.

Ed Rains, Assistant Chief of the U.S. Lake Survey, a graduate engineer who had been a hydraulics major at Michigan and who had a background of 20 years experience with matters relating to the Great Lakes and their connecting rivers.

Not present, but available by telephone was Mr. Samuel Sloan, a graduate engineer who had come to the Lake Survey in 1902 and who had recently retired at age 70. Mr. Sloan had devoted the past 30 years solely to study of lake levels and flow in connecting channels. He was recognized as an authority on the subject, and had recently been called back from retirement to present a paper at a joint meeting of the American Society of Civil Engineers and the Engineering Society of Canada.

At this point, the Chief Engineer of the Detroit Southern Railroad called and said that water along the Detroit River was getting close to its tracks. The Mayor of Algonac called again to say that people were traveling down the streets in rowboats. More calls were coming in. Bristol asked the District Executive to field the calls while he prepared for the meeting. "I think staff conferences without some kind of agenda are a complete waste of time," he commented. "This time especially we can't afford mistakes."

Exhibit A-1 Map Showing Rivers and Gage Locations

⊗ Denotes Gage Location

M I C H I G A N

LAKE
HURON

FORT GRATOT

DRY
DOCK.

ST.
CLAIR
RIVER

ALGONAG

LAKE
ST. CLAIR

~~6~~ G.P.Y.C.

DETROIT

FT. WAYNE

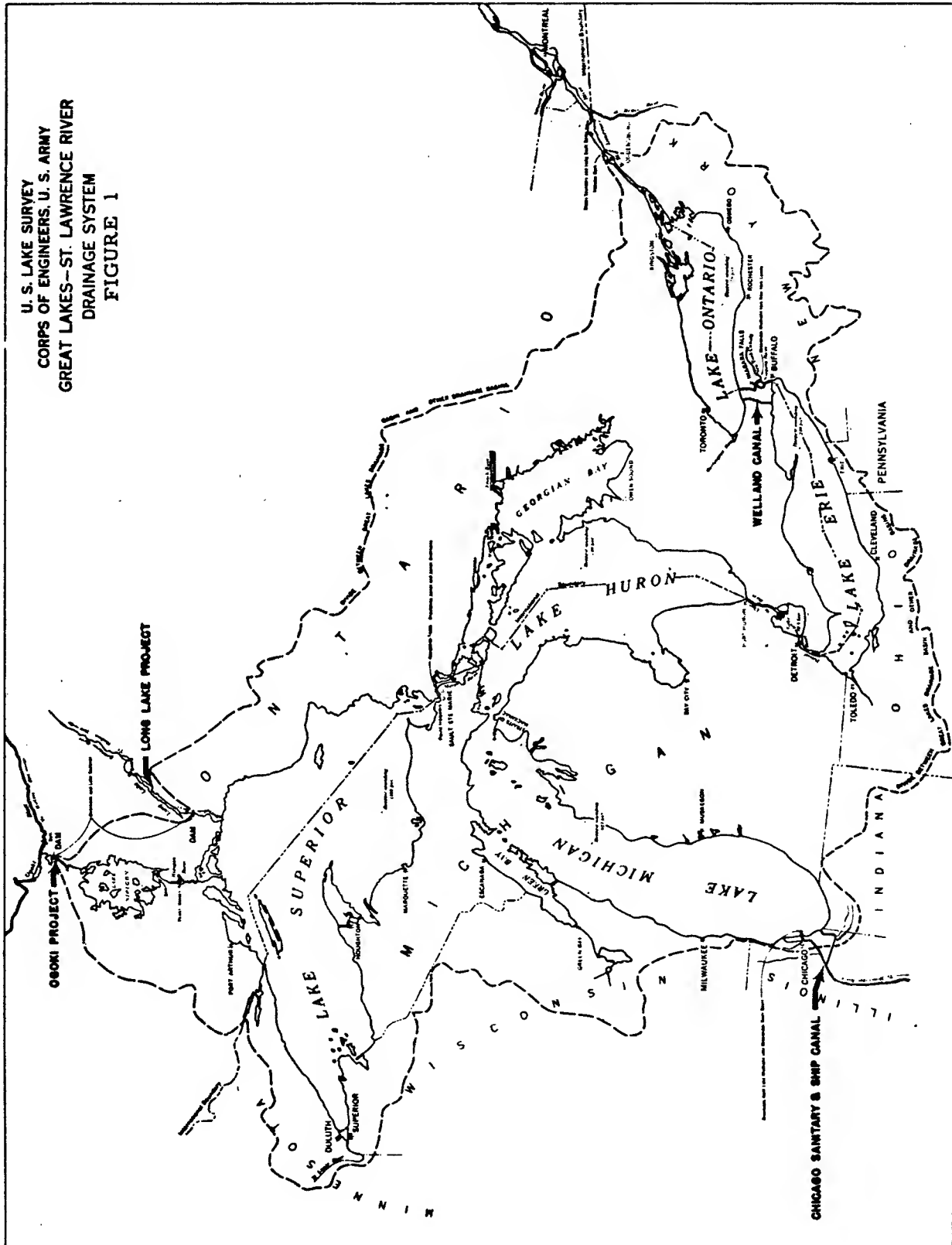
WINDSOR

DETROIT
RIVER

O N T A R I O

PRALTAR

LAKE
ERIE



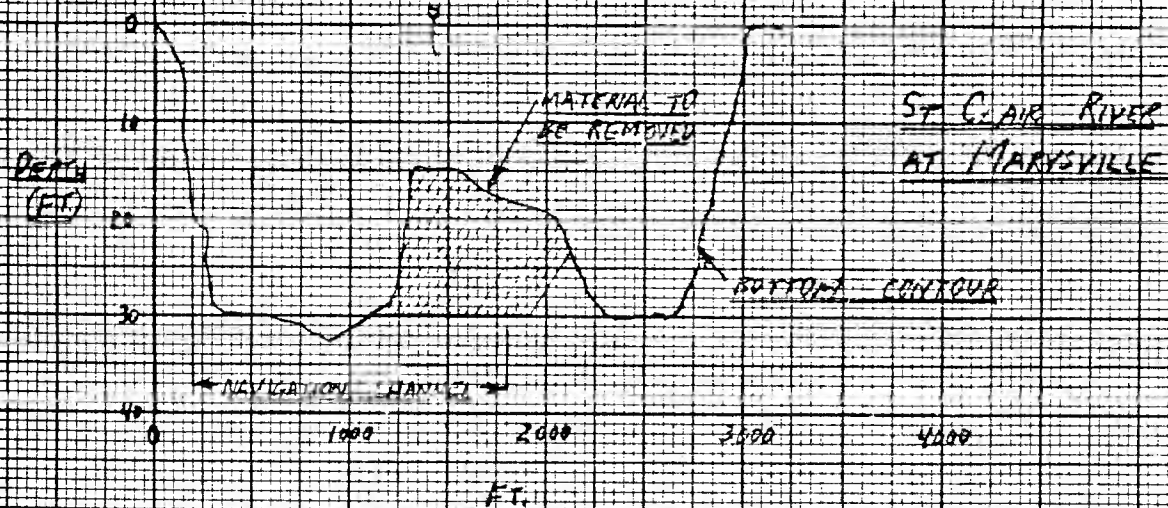
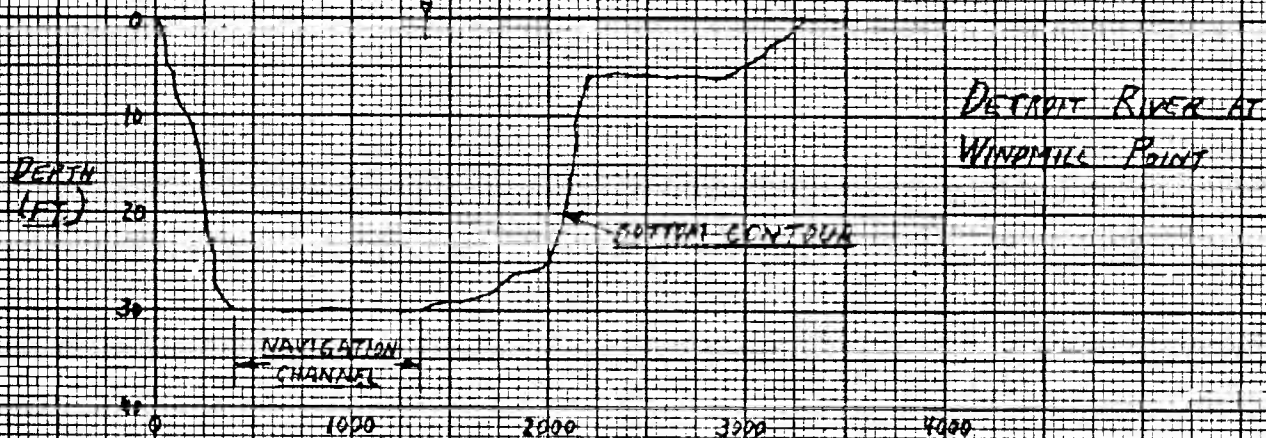


Exhibit A-3 Stage - Fall - Discharge Equations
for the St. Clair and Detroit Rivers

St. Clair River

Period	Equation
1937-1958	$Q = 73.515(.5HB + .5GPYC - 541.52)^2 (HB - GPYC)^{.5}$
1962-1967	$Q = 73.515(.5HB + .5GPYC - 540.84)^2 (HB - GPYC)^{.5}$

Detroit River

Period	Equation
1937-1958	$Q = 220.625(WP - 548.91)^2 (WP - GIB)^{.4}$
1962-1967	$Q = 220.625(WP - 548.46)^2 (WP - GIB)^{.4}$

HB = Harbor Beach Gage

GPYC = Grosse Pte. Yacht Club Gage

WP = Windmill Point Gage

GIB = Gibraltar Gage

Corps of Engineers
U. S. Army

MONTHLY AND ANNUAL FLOW
IN THOUSANDS OF CUBIC FEET PER SECOND
OF THE

U. S. Lake Survey
Detroit, Michigan

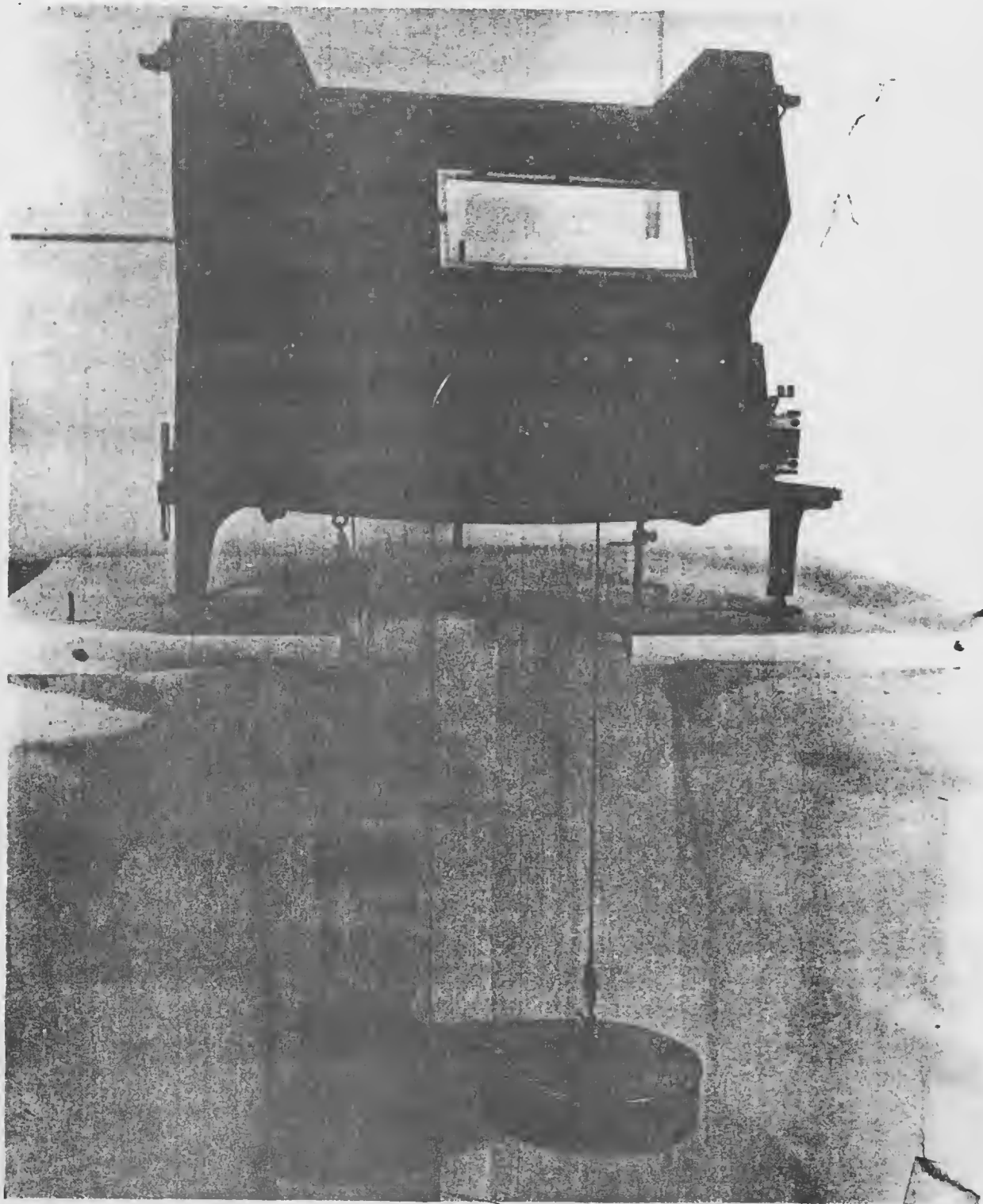
ST. CLAIR AND DETROIT RIVERS

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
1940	124	126	141	164	168	170	172	175	176	173	173	169	161
1941	133	115	149	163	175	175	172	170	169	174	174	175	162
1942	165	99	155	182	182	188	189	186	186	184	180	177	173
1943	118	133	172	185	181	194	210	213	209	207	204	196	185
1944	145	162	169	195	197	197	201	200	199	200	194	182	187
1945	150	161	186	188	195	200	202	200	200	198	195	177	188
1946	170	143	192	201	199	199	200	200	195	191	191	188	181
1947	154	143	182	188	190	194	202	204	202	200	198	195	188
1948	168	164	189	196	202	198	198	198	192	182	177	180	187
1949	181	177	150	179	179	179	180	180	176	172	169	166	174
1950	162	138	149	171	173	176	185	187	189	189	187	185	174
1951	169	170	185	194	201	205	211	213	213	216	218	204	200
1952	200	205	208	218	221	225	228	231	230	223	216	216	218
1953	213	205	207	212	213	218	222	223	220	215	209	204	213
1954	170	154	202	203	207	212	218	217	215	222	217	214	204
1955	201	188	202	206	208	212	210	208	199	193	189	186	200
1956	122	120	170	188	194	194	196	198	194	190	187	183	178

Exhibit A-4 Historical Flow Rates

File No. EGZA 4-5

AUTOMATIC WATER LEVEL RECORDER

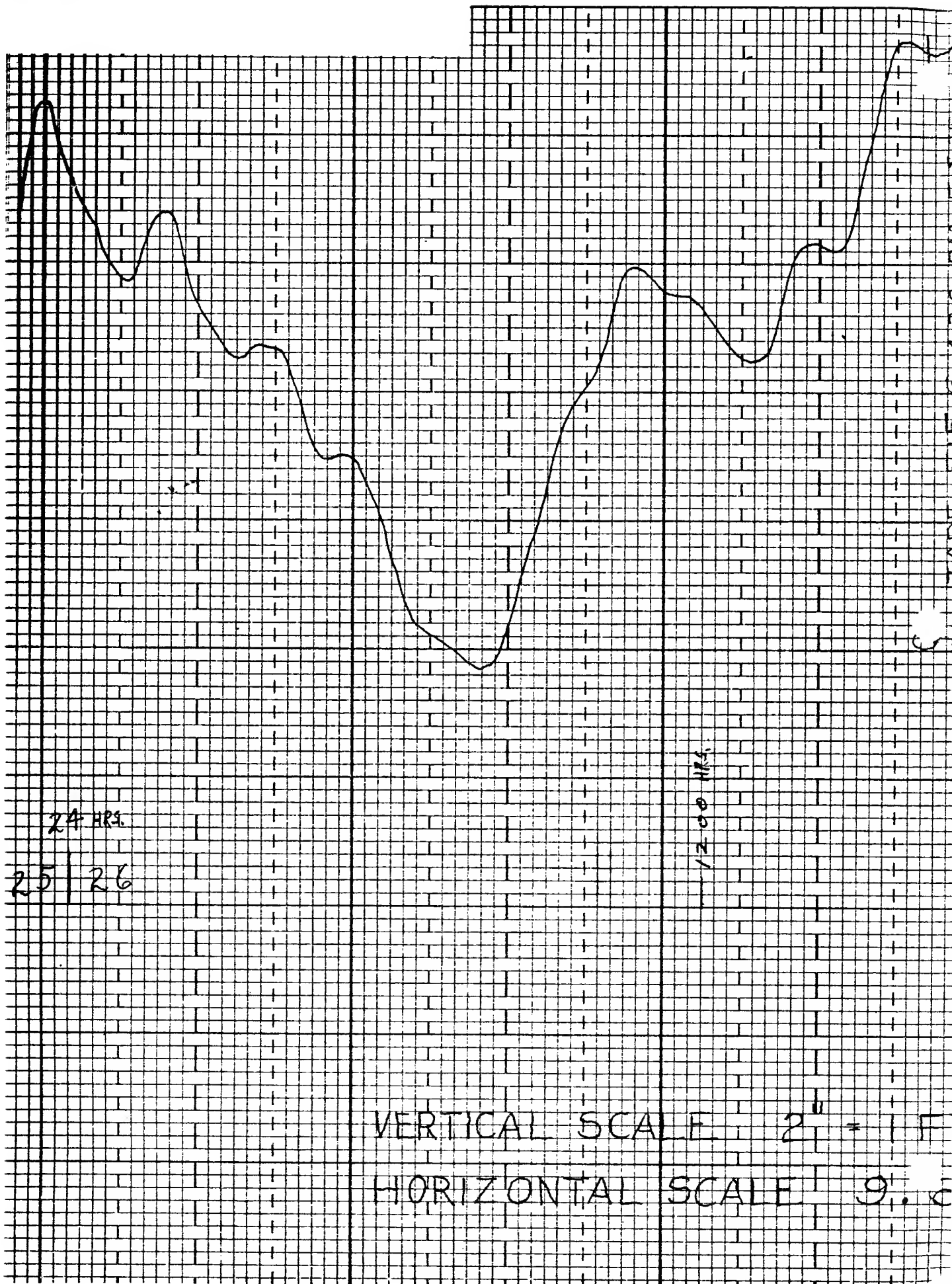


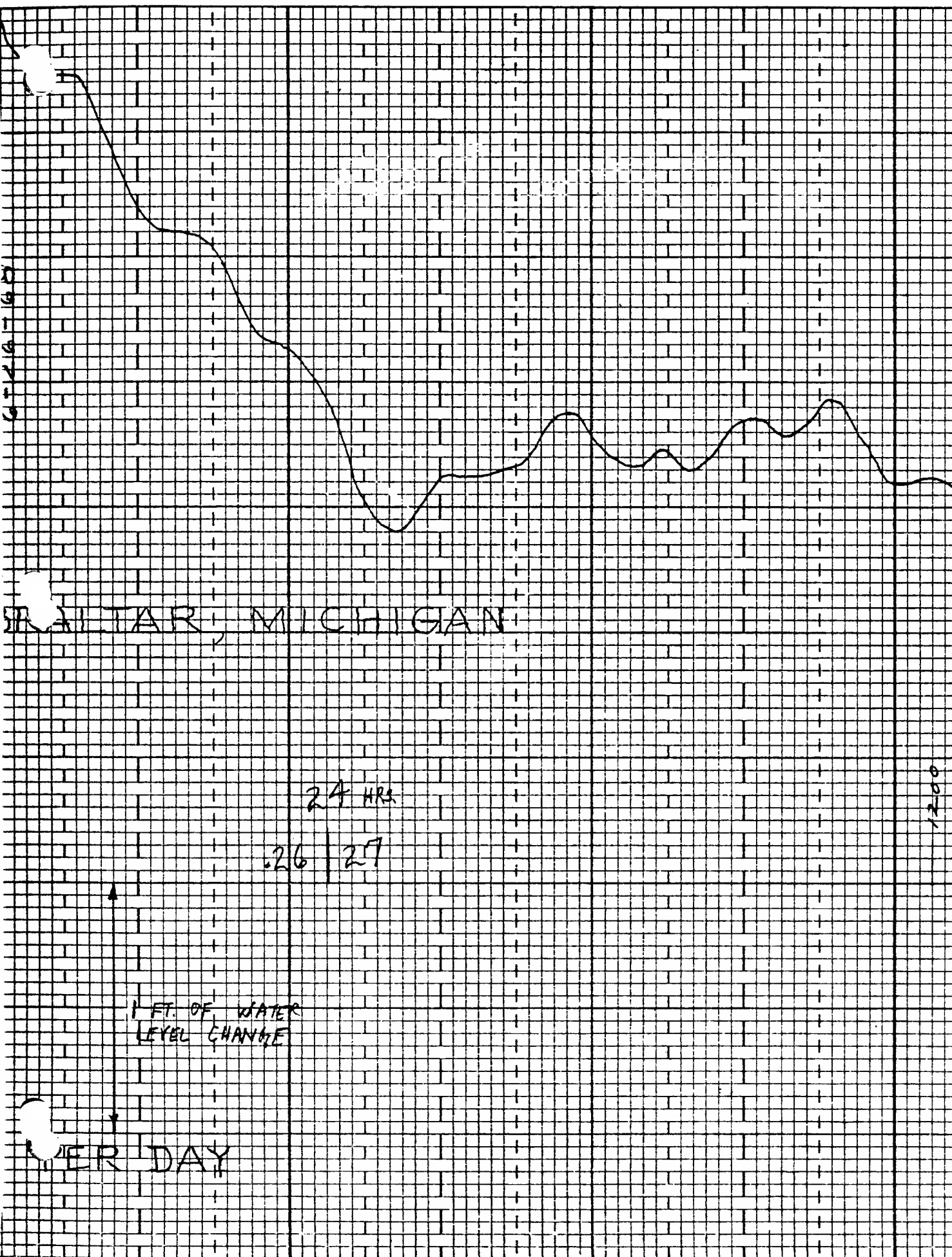
This Cable Attaches to float

USED BY U. S. LAKE SURVEY AT
NEARLY 50 GAGING SITES.

Exhibit A-6 Typical Gage Recording

(Size slightly reduced in printing the case)





CORPS OF ENGINEERS, U.S. ARMY
U.S. LAKE SURVEY
MONTHLY AND ANNUAL MEAN ELEVATIONS OF
ST. CLAIR RIVER
AT
ALGONAC, MICHIGAN

YEAR	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	MEAN
1898													
1899						576.33							
1900													
1901					575.95								
1926							574.84	574.96	574.97	574.01	574.91	575.16	
1927				574.95	575.26	575.55	575.76	575.70	575.44	575.30	574.99	575.24	
28	575.27	574.67	574.42	575.41	575.61	575.95	576.35	576.37	576.20	576.06	576.13	576.05	
29		576.84	576.64	577.01	577.58	577.62	577.79	577.65	577.33	576.95			
1947										576.57	576.31		
1952								578.12	577.92	577.42	576.96	576.85	
1953	576.85	576.93	576.93	577.06	577.26	577.55	577.69	577.65	577.38	577.01	576.65	576.46	577.12
1954	576.23	576.06	576.65	576.85	576.98	577.13	577.27	577.20	577.03	577.30	577.18	576.99	576.90
1955	577.30	576.99	577.15	577.14	577.24		577.22	577.07	576.67	576.42	576.14	575.94	
1956	574.47	574.39	575.53	575.85	576.58	576.55	576.69	576.74	576.55	576.09	575.75	575.55	575.90
1957	575.29	575.33	575.49	575.63	575.86	575.99	576.34	576.15	575.95	575.61	575.36	575.36	575.70
1958	574.88	574.43	575.04	575.03	575.05	575.19	575.39	575.38	575.26	574.94	574.66	574.78	575.00
1959	574.25	574.62	574.83	575.05	575.30	575.42	575.40	575.34	575.21	575.12	575.00	575.08	575.05
1960	575.53	574.94	575.38	575.74	576.10	576.56	576.75	576.83	576.65	576.34	575.92	575.83	576.08
1961	575.78	575.45	575.51	575.79	576.20								

* PARTIAL RECORD

FILE EED2-1

ELEVATIONS ARE IN FEET AND REFER TO MEAN TIDE AT NEW YORK, 1935 DATUM

Jack Bristor (B)

Open Channel Flow

Jack Bristor opened the meeting by asking if the water had actually risen and if there really was a problem. Mr. Brown rejoined that there certainly was a problem. He said that tried-and-true gages, some of which had operated without repair for over 75 years and which were being read both automatically and manually, simply could not be in error. Mr. Darcy added that the people in Algonac, which was very low in elevation, often became excited, but that the Detroit Southern Railroad engineer was a "solid citizen who would never call unless he was really concerned." Jack commented that the whole situation seemed unreal. Mr. Rains answered that the Lake Survey had studied water levels for over 100 years, and that he was sure the present situation was unprecedented.

Mr. Jones asked for the latest information on the water levels. Mr. Brown said that Gibraltar and Ft. Wayne were rising, Algonac was holding steady, but that the Lake St. Clair gage at the Grosse Point Yacht Club was out of action. Bristor said he wanted to get to the heart of the matter

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of why the water was rising, and that he felt the key to this related either to the flow or the ice or both. Mr. Brown said that the present flow, which was based on the present differential elevation of Lakes Huron and Erie, was high, but had been higher in the past, without the current phenomenon being observed. It seemed to be a high for February, however.

Jack asked about the effect of surface ice on the flow of a large river like the Detroit and St. Clair Rivers. Mr. Rains said that not too much was known about the effects of ice, but that both rivers had been carefully measured during severe winters by stream-gaging through the ice, and that ice seemed to cause little change in the rate of flow. Actually, most people believed that the ice merely floated on the surface in the same way as a boat did. Mr. Darcy and Mr. Ash said that it simply had not been cold enough for these deep rivers to have frozen solid, that actually the present basic ice cover was only 4 or 5 inches thick, and that the irregular broken pieces of ice from the freeze prior to the thaw were only about 6 to 8 inches thick. Bristor then asked if the windrowing of the broken ice from the previous freeze could have formed an ice dam (wholly or partially) which could impede flow. Mr. Brown, Mr. Ash, and Mr. Rains said that they were "ex-River Rats" who had worked around the rivers winter and summer, and it just never seemed to have happened that way. They had talked to pilots and crews of the Coast Guard icebreakers, who said that in these large, deep, wide rivers, ice jams under conditions like the present just never seemed to come about. The entire staff agreed fully with the opinion that the surface ice was floating on top of the water, and not impeding flow.

Bristor's secretary appeared in the meeting and said: "Colonel, you just have to take this call." Jack left the room and talked to a lady who lived near the corner of Eight Mile Road and Woodward Avenue (the highest elevation in Detroit). She said that the streets were full of water and asked what should she do about it. Stifling an impulse to tell her to "run for the woods," Bristor said he would look into it. He then asked his secretary to phone the Detroit Police. He returned to the conference room, not without a glance outside to see if his own building were awash.

Jack recalled an experience three months earlier which had occurred on the St. Mary's River which he thought might have some bearing on the present situation. Three power plants and control gates regulated the flow in the St. Mary's River. The River was flowing at its maximum rate when the temperature dropped to -27°F . The power plants went out of operation, apparently due to a phenomenon known as "frazil ice," which Webster's Third International Dictionary defines as "ice crystals or granules sometimes resembling slush that are found in turbulent water." Such ice is seldom seen because it forms beneath the surface, in such places as hydroelectric inlets. Its consistency is reportedly similar to that of shaved ice, and reportedly it is very unstable. Bristol had heard it referred to as "an isotope with a half-life of 10^{-10} seconds." When the power plants on the St. Mary's went out of operation, apparently the frazil ice had disappeared, allowing flow to resume. The control gates were then closed partially, further reducing the flow so the power plants could be placed back in operation. With the reduced flow, conditions returned to normal.

It occurred to Jack that frazil ice might be causing restriction of flow in the Detroit and St. Clair rivers, and he suggested this idea to the group. Mr. Jones said that it was highly unlikely, frazil ice being so unstable. He could not imagine frazil ice lasting 10 or 11 hours. Further, it just had not been cold enough to produce frazil ice -- that it had never been observed below the St. Mary's River 300 miles to the north. Mr. Brown said that Mr. Sloan had told him of a man who claimed that the Clinton River, a small tributary of Lake St. Clair, had "frozen solid" about 1875, but that there were no flow observations on the Clinton River available prior to the 1930's. Mr. Rains observed that frazil ice always seemed to be a localized phenomenon and he could not visualize it extending for any distance along a river as large as the St. Clair or Detroit Rivers. Bristol wondered if it could be a combination of flow and some kind of ice -- if it were possible to correlate flows, temperatures, and ice in past records to see if the present combination had ever existed, and what the outcome had been, i.e., had the rivers adjusted themselves? Mr. Brown said that it would take 3 weeks just to correlate flows and temperatures,

but that reports of ice had been made only for a few years, and that even these reports were quite general in nature.

The secretary returned with the news that the Detroit Police reported water over the curb at the corner of 8 Mile Road and Woodward Avenue. Mr. Ash called the Detroit Water Department, who said that a broken water main had caused the flooding at the corner, but that the main burst because the Army Engineers had raised the lake level of the inlet on Lake St. Clair so high that the main could not withstand the pressure.

Breathing a sigh of relief, Jack Bristor then said that maybe the bottom of the rivers should be considered too, and he asked if a shoal of bottom material could have formed. Mr. Ash said that while there was some loose material in the St. Clair River, the bottom was relatively stable and that the Detroit River was pretty much of a hard bottom river. Both were considered to be clear water streams, not at all like the meandering alluvial rivers.

At this point, the aerial observer called Col. Bristor, giving the following information:

The St. Clair and Detroit Rivers appeared to consist of solid ice upon which the irregular chunks from the previous freeze were piled.

Lake St. Clair was somewhat the same around the edges, but was more of a solid sheet of ice toward the center.

While the ice was irregular and spotty, there was no evidence of any obstruction or "ice bridge" or "ice dam" or any localized pile-up of ice.

No one offered any other reason for the rising surface of the river system.

Bristor then asked if changing the flow in the St. Mary's River would accomplish anything. Mr. Brown replied that the storage in Lake Michigan-Huron was so vast that even complete stoppage of the St. Mary's River would have no measurable effect for several weeks. Similarly, reducing the flow of the Niagara River at the outlet of Lake Erie would not measurably raise the level of Lake Erie for over a month or two.

Bristor said to Mr. Darcy that he had previously mentioned icebreakers and asked what the icebreaker situation was. Mr. Darcy replied that the U.S. Coast Guard had icebreakers at Detroit and Toledo. Bristor then called Commander Slossor of the Coast Guard District in Cleveland who furnished the following information:

While the Coast Guard icebreakers were not under the operational control of the Army, the District Commander would be willing to dispatch the icebreakers for flood control purposes upon request.

The icebreakers were maintained in a high state of readiness, and could cast off in a matter of minutes.

Experience during similar ice conditions indicated that the icebreakers would have no trouble maintaining passageway, that they would not encounter any obstructions, and that probably what would happen would be that, with no water traffic behind the icebreaker, the ice would flow together and eventually consolidate by freezing.

The icebreakers were expensive to operate, and there were other potential users, so that a request to utilize them should not be undertaken lightly.

He had no opinion as to what good the icebreakers would do.

However, the staff of the two Districts expressed a definite opinion about the icebreakers, which Jack summarized as follows:

The icebreakers could not alter the flow in the rivers. The elevations of Lake Huron and Lake Erie controlled that.

If either surface ice or frazil ice were obstructing the flow of the rivers, to the extent that they could hold back 200,000 c.f.s. of flow, the icebreakers would have no chance of penetrating the obstruction.

Use of the icebreakers would be a waste of Government money, as there was no known reason as to how they could do any possible good.

The icebreakers would not open a waterway through the ice through which the water could flow because the ice would close in on the path opened by icebreaker. In other words, the ice would flow together shortly behind the stern of each ship and freeze once more.

Any effect the icebreaker might have would be strictly local. For instance, many parts of the rivers were over a mile wide; the icebreaker was only 20 feet wide, and the propeller only 4 feet in diameter.

The ice cover would dampen any waves created by the bow of the icebreaker. Turbulence from the ship pushing aside the water and ice would not be felt beyond 100 feet from the icebreakers. This was an insignificant distance in a 5,000+ foot wide river.

Likewise any effect of the propeller of the icebreaker would also be local and would affect only a small part of the cross-section of the river.

Bristor asked Mr. Brown to call Mr. Sloan to see if Mr. Sloan could furnish any useful information or opinions. Then he asked what would happen if the water continued to rise. As there had never been any flood threat of this nature, no study of such a problem had ever been undertaken and no stage-damage curves had been prepared. From a knowledge of the area, there was a general consensus of opinion that continued rising water for another day would cause great damage.

Mr. Brown returned and said that Mr. Sloan could shed no light on the situation, but concurred in the opinions previously expressed by the group.

At this time, it was reported that the Dry Dock gage was out of action.

It was getting around to the lunch hour and Bristor believed he had to act.

Jack Bristor (C)

Open Channel Flow

Upon leaving the conference room, Jack Bristor went to the telephone and asked the Coast Guard:

To dispatch the icebreaker at Detroit to proceed across Lake St. Clair and up the St. Clair River to Port Huron.

To dispatch the icebreaker at Toledo to proceed across Lake Erie and up the Detroit River to Detroit.

To request the crews to note any obstacles encountered.

Lake in the afternoon, Mr. Darcy told Mr. Bristor that the icebreaker in the St. Clair River had passed the Algonac gage and that the water started to drop as soon as the icebreaker passed. Half an hour later, a similar report was received from the lower gage on the Detroit River. By the next morning, the St. Clair River gage readings had all returned to normal. The Gibraltar gage also dropped as the icebreaker passed, but went back up later in the night. The icebreaker made another run through the lower Detroit River and the gage dropped. On the next two nights the same pattern was repeated.

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The Coast Guard reported that each trip was completely uneventful, that each icebreaker had steadily plowed its way through the ice for the entire trip, that no bump or thud or jolt was encountered at any time, and that the ice flowed together and froze behind the icebreaker. Darcy went along on one of the trips, returning with a bad case of windburn from standing on the bow, but without any evidence of anything remotely resembling an obstruction in the river.

Warmer weather came and the ice disappeared. Although Jack did not think he merely "lucked out", he still does not understand why the water level dropped after the icebreaker passed.

INSTRUCTOR'S NOTE

Little technical sophistication is required to tackle this case. It is intended primarily to arouse student interest by presenting a dramatic situation anyone can appreciate and to stretch perspective for cases to follow by describing a situation where clearly technical aspects represent only one part of a broad spectrum of considerations for prescribing action.

Assignments for Part A

1. Read the case and formulate a plan of action for Mr. Bristor. (This assignment can require submission of a written recommendation.)
2. Be prepared to explain your recommendation and the reasoning behind it in class discussion.
3. (Alternate) Formulate an agenda for the meeting Bristor plans to hold.

Class Discussion

Possible questions for use by the instructor include the following:

1. What is the problem? What evidence serves to support this definition? What different ways can the problem be defined? Should Bristor stop and take time to define the problem? What implicit or explicit definition should he work from? (Students here will tend to overlook possibilities as individuals which they can see revealed through contributions of others in the group. For instance, what press release should Bristor have ready?) Is there a problem? (Students should look at the records. Some will use numbers better than others.)
2. What may be causing the high gage readings? Some possibilities include:
 - a. Frazil ice (see later sections)
 - b. Coincident gage malfunctions. Some students will study Exhibit A-5 to speculate about what might stick, freeze, break, stretch, etc.
 - c. Reader error.
 - d. Submarine blockage of some sort.
 - e. Unusual inflow (The river system can be described in terms of a control volume for formal illustration of the law of conservation of mass if desired)
 - f. Wind effects.

Prepared by Karl H. Vesper, Associate Professor, Mechanical Engineering Department, University of Washington, December 1970. Published in the Engineering Case Library, Stanford University.

3. What alternatives does Bristor have? Some possibilities include:

- a. Do nothing (until when?)
- b. Ask advice of others (whom?)
- c. Sound the alarm (to whom? say what?)
- d. Analyze the data more fully, or request more data (what?)
- e. Call a meeting (his plan)
- f. Other items and combinations of the above.

4. What should Bristor consider in formulating his actions?

- a. The authority and responsibility vested in him formally by his job?
- b. What seems to be happening in the river flow?
- c. The resources at his command (Can he use dynamite?)
- d. Effects possible on people's lives, and on property. (What is the trade-off between these two?)
- e. Cost of possible actions.
- f. The joint effects of his actions in conjunction with actions which others might independently be taking. (Maybe somebody else is already sending an icebreaker or using dynamite.)

As suggestions to answer the above questions come in they can be noted on the board, and a very complex picture will gradually form. This complexity will tend to steer the class away from making a decision and formulating a definite plan. Then the question can be raised as to how long Bristor can debate about what he should do and what the consequences of long delay might be. This should focus both the drama of a crucial role which an engineer can play and also the breadth of considerations he must be aware of. Allowing students to leave class "up in the air" about these two facts may serve to make the lesson more forceful. Alternatively, the instructor can relieve some of the tension by allowing a "vote" on action and/or putting forth views of his own.

Parts B and C

The action which Bristor actually took is described in these succeeding parts, which can be assigned for reading after Part A has been discussed. Part B can be assigned for the class following discussion of A, the assignment again to be formulation of action for Bristor at the end of the chapter. The first half of the second class period then can be devoted to similar discussion as in the first class. One issue to be settled is whether to send an icebreaker. Another can be the question of how effectively Bristor has thus far handled the situation. Could better provisions for an emergency such as this one have been made beforehand?

The second half of the second hour then can be spent on Part C. Three or four minutes should be sufficient for reading it, leaving the remaining time to discuss (1) how well Bristol in retrospect handled the problem, and (2) what study should now be done to profit maximally from this experience and to prepare for possible emergencies of this sort in the future. At this point the question of cost and the probability of such an event occurring again should be kept in mind. Some students will probably want to forget these aspects and "do everything" they can think of to treat possible problems of the future.